CHAPTER 4

DRAFTING: GEOMETRIC CONSTRUCTION

Knowledge of the principles of geometric construction and its applications are essential to an Engineering Aid, As a draftsman, you must be able to "construct" or draw any of the various types of lines. In a line drawing, a line may be a straight line, a circle, an arc of a circle or a fillet, a circular curve, a noncircular curve, or a combination of these basic types of lines.

You must also be able to construct line drawings at specified angles to each other, various plane figures, and other graphic representations consisting exclusively of lines. This chapter provides information that will aid you in drawing different types of geometric constructions.

STRAIGHT LINES

One method of drawing horizontal and vertical lines, perpendicular and parallel lines, and inclined lines is by using a straightedge (or a T square) with a triangle. Another practical method of constructing straight lines is by using a drafting compass.

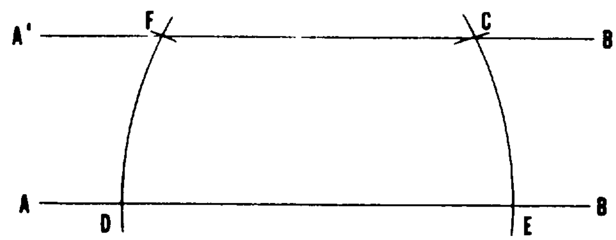

Figure 4-1.-Drawing a line through a given point, parallel to another line.

Figure 4-1 shows a method of drawing a line parallel to another line. Here, the line is to be drawn through given point C. To draw a line through C parallel to AB, place the needlepoint of the compass on any point D on AB, and strike arc CE. Shift the needlepoint to E, maintaining the same radius, and strike arc DF. Set a compass to a chord of arc CE, and lay off the chord DF from D, thus locating point F. A line drawn through F and C is parallel to AB.

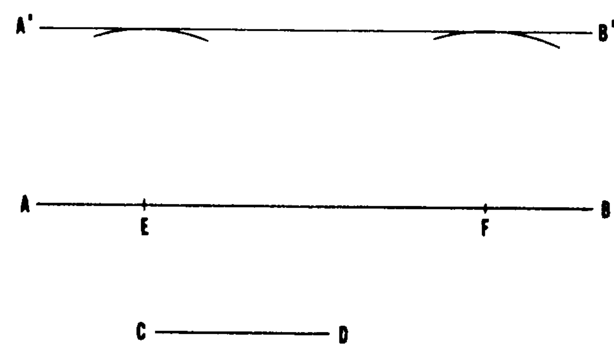

Figure 4-2.-Drawing a parallel line at a given distance from another line.

Figure 4-2 shows another method of drawing one line parallel to another, this one being used when the second line is to be drawn at a given distance from the first. To draw a line parallel to AB at a distance from AB equal to CD, set a compass to the length of CD, and, from any points E and F on AB, strike two arcs. A line A'B' drawn tangent to (barely touching) the arcs is parallel to AB, and located CD distance from AB.

In the preceding chapter, you learned how to draw a line perpendicular to another by the use of a straightedge and a triangle. Two other methods of solving this problem are explained below.

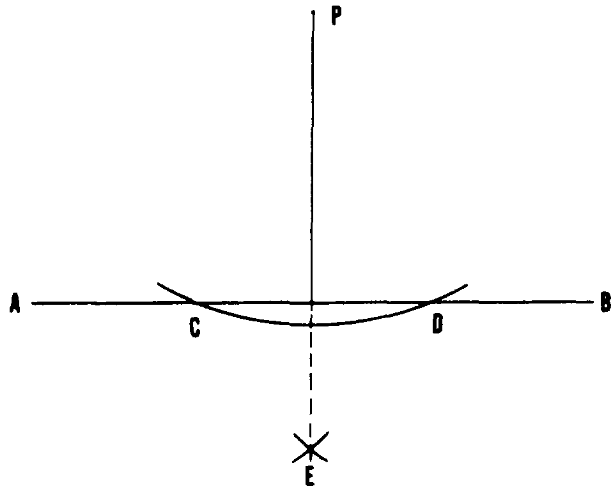

Figure 4-3.-Dropping a perpendicular from a given point to a line.

Figure 4-3 shows a method of dropping a perpendicular from a given point to a line, using a compass. To drop a perpendicular from point P to AB, set the needlepoint of the compass at P and strike an arc intersecting AB at C and D. With C and D as centers and any radius larger than one-half of CD, strike arcs intersecting at E. A line from P through E is perpendicular to AB.

Figure 4-4 shows a method of erecting a perpendicular from a given point on a line. To erect a perpendicular from point P on AB, set a compass to any convenient radius, and, with P as a center, strike arcs intersecting AB at C and D. With C and D as centers and any radius larger than one-half of CD, strike arcs intersecting at E. A line from P through E is perpendicular to AB.

BISECTION OF A LINE

A line can be bisected by trial and error with dividers; that is, by setting the dividers to various

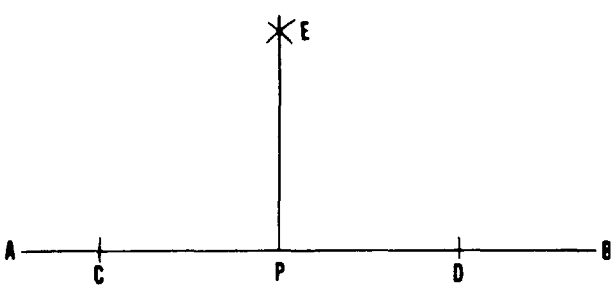

Figure 4-4.-Erecting a perpendicular from a given point on a line.

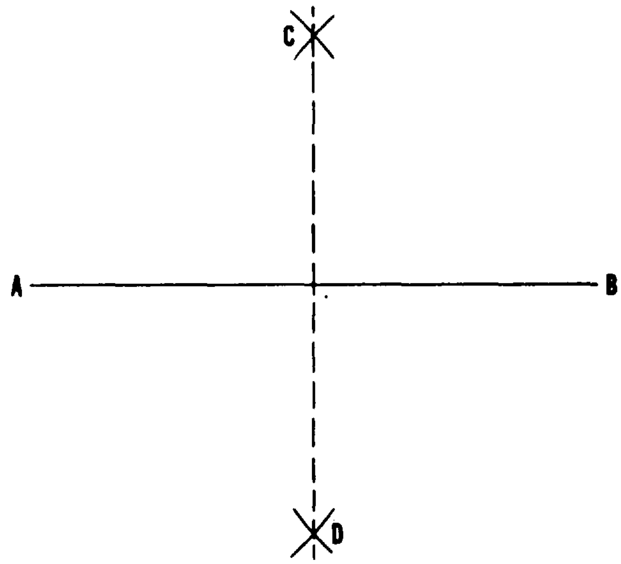

Figure 4-5.-Bisecting a line.

spreads until you find one that correctly measures one-half the length of the line.

Geometric construction for bisecting a line is shown in figure 4-5. To bisect the line AB, use the ends of the line, A and B, as centers; set a compass to a radius greater than one-half the length of AB; and strike arcs intersecting at C and D. A line drawn from C through D bisects AB.

DIVISION INTO ANY NUMBER OF EQUAL PARTS

A line may be divided into more than two equal parts by trial and error with the dividers. Geometric construction for dividing a line into any number of equal parts is shown in figure 4-6. To divide AB into 10 equal parts, draw a ray line CB from B at a convenient acute angle to AB. Set a compass to spread less than one-tenth of the length of CB, and lay off this interval 10 times from B on CB. Draw a line from the 10th interval

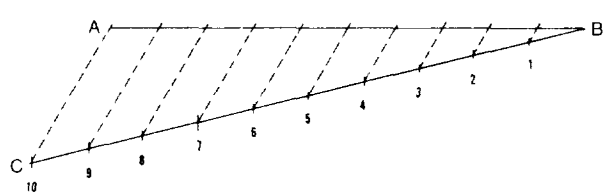

Figure 4-6.-Dividing a line into any number of equal parts.

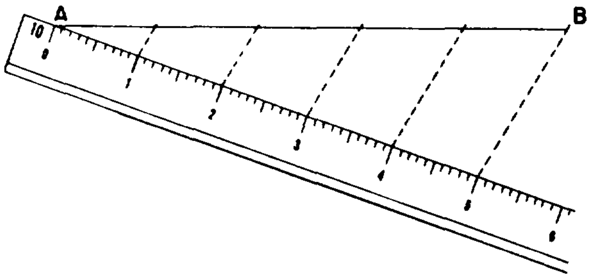

Figure 4-7.-Using a scale to lay off equal intervals on a random line.

to A, and project the other points of intersection from CB to AB by lines parallel to the first one. The projected points of intersection divide AB into 10 equal parts.

Figure 4-7 shows how you can use a scale to lay off equal intervals on the ray line.

DIVISION INTO PROPORTIONAL PARTS

Figure 4-8 show's a method of dividing a line into given proportional parts. The problem here is to divide the line AB into parts that are proportional as 2:3:4. Lay off ray line CB from B at a convenient acute angle to AB. Set a compass to a convenient spread, and lay off this interval from B on CB the number of times that is equal to the sum of the figures in the proportion (2 + 3 + 4 = 9). Draw a line from the point of intersection of the last interval to A, and use a straightedge and triangle to project the second and fifth intercepts on CB to AB by lines parallel to the first one. The projected intercepts divide AB into segments that are proportional as 2:3:4.

Here again, you could use a scale to lay off nine equal intervals on CB.

DIVISION ACCORDING TO A GIVEN RATIO

You may be required to divide a line into parts so that the ratio between the whole line and one of the parts is the same as that between two other lines. A method

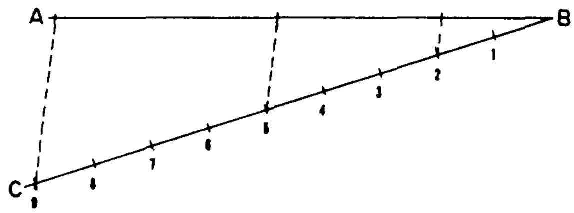

Figure 4-8.-Dividing a line into proportional parts.

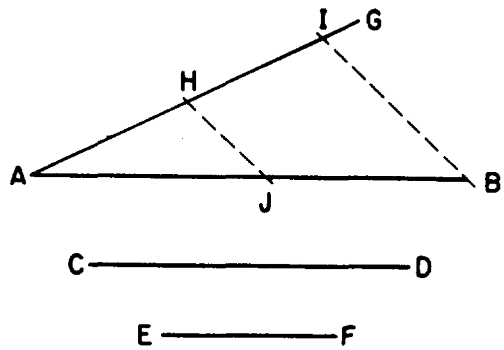

Figure 4-9.-Dividing a line into parts according to a given ratio.

of doing this is shown in figure 4-9. Here, it is required that AB be divided so that the ratio between AB and a part of AB is the same as the ratio between CD and EF. From A, draw a ray line AG at a convenient acute angle from AB. On AG, lay off AH equal to EF and AI equal to CD. Draw a line from I to B, and use a straightedge and triangle to project H to J on a line parallel to IB. The ratio of AB to AJ is the same as that of CD to EF.

ANGLES

You already know how to lay off an angle of given size with a protractor, or trigonometrically by the use of the tangent or the chord method.

TRANSFER OF AN ANGLE

There is a geometric construction for laying off, on another part of the same drawing or on a different drawing, an angle

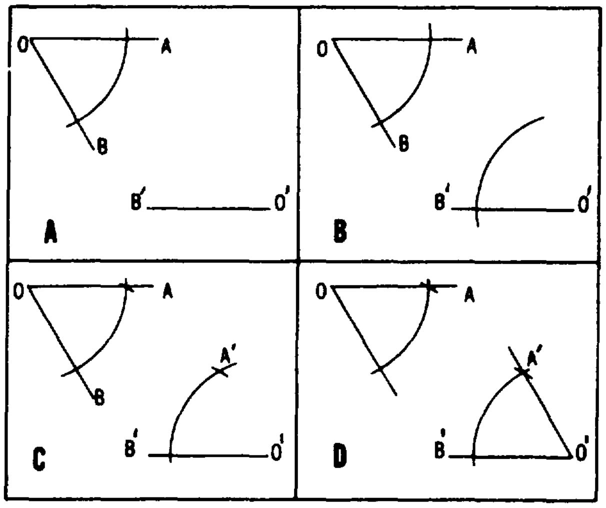

Figure 4-10.-Transferring an angle.

equal in size to one that is already drawn. This procedure, called transferring an angle, is shown in figure 4-10. Here, the draftsman desired to lay off from O´ a line that would make an angle with B´O´ equal to angle BOA. To do this, draw an arc through OB and OA, with O as a center, as shown in figure 4-10, view A. Then, draw an arc of the same radius from B´O´, with O´ as a center, as shown in figure 4-10, view B. Next, measure the length of the chord of the arc between OB and OA and lay off the same length on the arc from B´O´, as shown in figure 4-10, view C. A line drawn from O´ through A´ makes an angle with B´O´ equal to angle BOA, as shown in figure 4-10, view D.

BISECTION OF AN ANGLE

To bisect an angle means to divide it in half. If you know the size of the angle, you can bisect it by simply dividing the size by 2 and laying off the result with a protractor.

Geometric construction for bisecting an angle is shown in figure 4-11, To bisect the angle AOB, first lay off equal intervals from O on OA and OB. With the ends of these intervals as centers, strike intersecting arcs of equal radius at P. Draw a line from O through the point of intersection of the arcs, P. The line OP bisects angle AOB.

PLANE FIGURES

This section explains how to construct certain plane figures, such as the triangle, rectangle, square, and regular polygon. You must understand the geometrical construction of plane figures because they appear in engineering drawings.

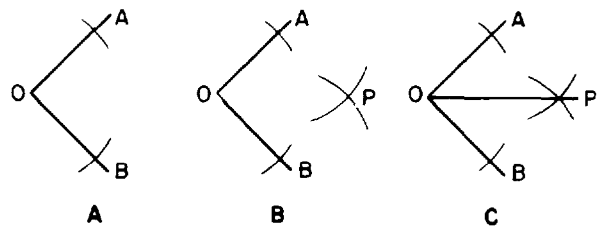

Figure 4-11.-Bisecting an angle.

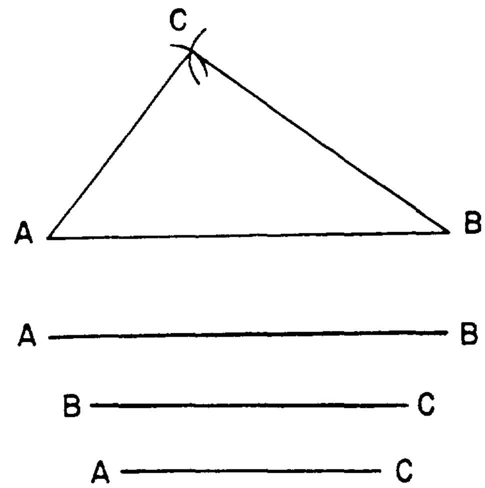

Figure 4-12.-Constructing a triangle with three sides given.

TRIANGLE: THREE SIDES GIVEN

To draw a triangle with three sides given, first draw a straight line AB, equal in length to one of the given sides (fig. 4-12). With A as a center, strike an arc with a radius equal to the given length of the second side. With B as a center, strike an intersecting arc with a radius equal to the length of the third side. Draw lines from A and B to the point of intersection of the arcs.

RIGHT TRIANGLE: HYPOTENUSE AND ONE SIDE GIVEN

Figure 4-13 shows a method of drawing a right triangle when the hypotenuse and one side are given. The line H is the given hypotenuse; the line S is the given side. Draw AB equal to H. Locate the center of AB (by bisection), and, with the midpoint as a center and a radius equal to one-half of AB, draw the semicircle from A to B as shown. Set a compass or dividers to the length of S, and, with A as a center, strike an arc intersecting the semicircle at C. Draw AC and BC.

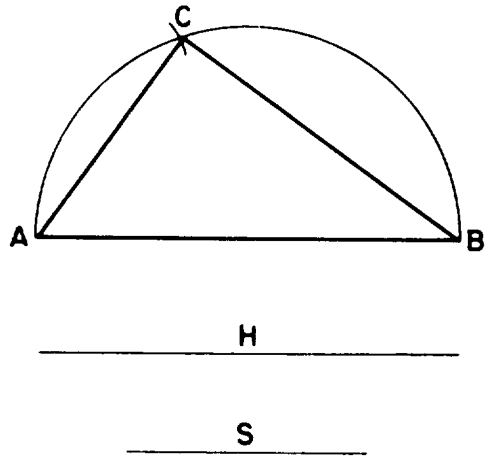

Figure 4-13.-Constructing a right triangle with hypotenuse and one side given.

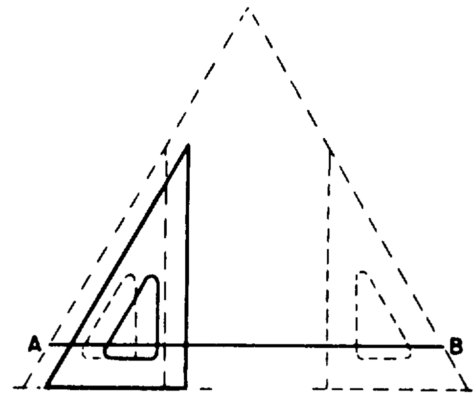

Figure 4-14.-Equilateral triangle with a given length of side AB.

EQUILATERAL TRIANGLE: LENGTH OF SIDE GIVEN

To construct an equilateral triangle when the length of a side is given, you can follow the method previously described for constructing a triangle when the length of each side is given. The sides of an equilateral triangle are equal in length.

Each angle in an equilateral triangle measures 60°. This fact is applied in the method of constructing an equilateral triangle with given length of side, such as the one shown in figure 4-14. Simply use a 30°/60° triangle and a T square or straightedge to erect lines from A and B at 60° to AB.

EQUILATERAL TRIANGLE IN A GIVEN CIRCUMSCRIBED CIRCLE

A circumscribed plane figure is one that encloses another figure, the circumscribed figure being tangent to the extremities of the enclosed figure. An inscribed plane figure is one that is enclosed by a circumscribed figure.

Figure 4-15 shows you how to inscribe an equilateral triangle within a given circumscribed circle. Draw a vertical center line intersecting the given circle at A and B. With B as a center and a radius equal to the radius of the circle, strike arcs intersecting the circle at C and D. Lines connecting A, C, and D form an equilateral triangle.

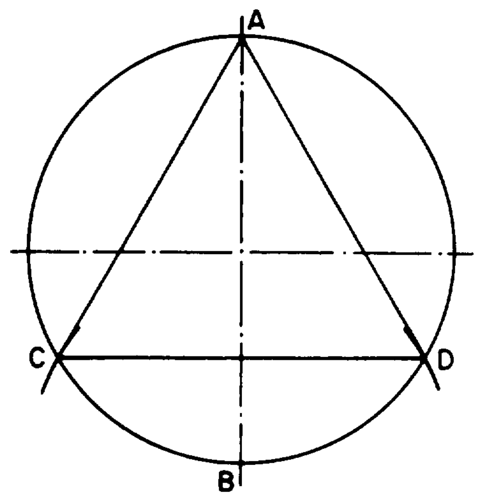

Figure 4-15.-Equilateral triangle in a given circumscribed circle.

EQUILATERAL TRIANGLE ON A GIVEN INSCRIBED CIRCLE

Figure 4-16 shows one method of circumscribing an equilateral triangle on a given inscribed

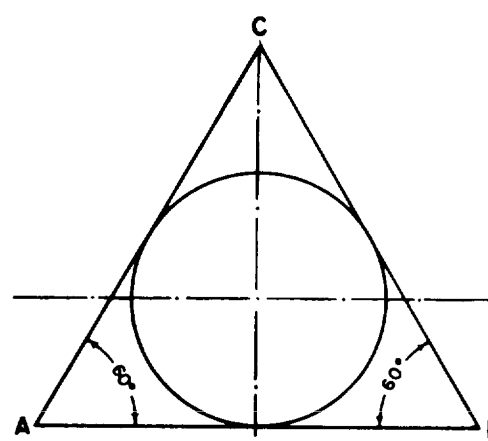

Figure 4-16.-Equilateral triangle on a given inscribed circle: one method.

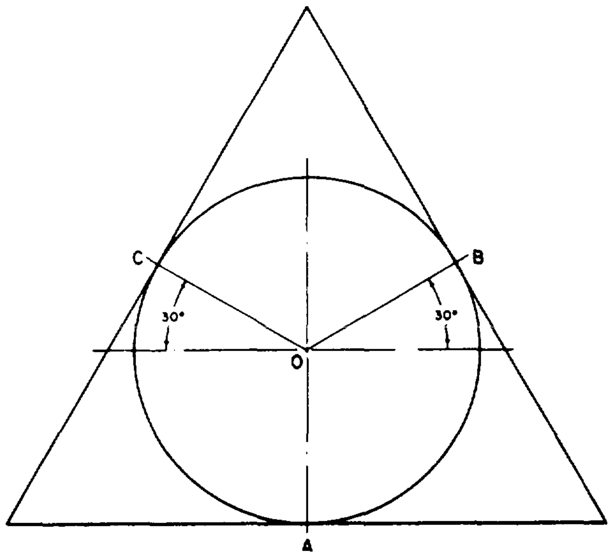

Figure 4-17.-Equilateral triangle on a given inscribed circle: another method.

circle. Draw AB parallel to the horizontal center line of the circle and tangent to the circumference. Then use a 30°/60° triangle to draw AC and BC at 60° to AB and tangent to the circle.

Another method of accomplishing this construction is shown in figure 4-17. Draw radii at 30° to the horizontal center line of the circle, intersecting the circumference at C and B. There is a third point of intersection at A, so you now have three radii: OA, OB, and OC. Draw the sides of the triangle at A, B, and C, tangent to the circle and perpendicular to the relevant radius.

RECTANGLE: GIVEN LENGTH AND WIDTH

To construct a rectangle with a given length and width, draw a horizontal line AB, equal to the given length. With a straightedge and triangle, erect perpendiculars from A and B, each equal to the given width. Connect the ends of the perpendiculars.

SQUARE: GIVEN LENGTH OF SIDE

You can construct a square with a given length of side by the method described for constructing a rectangle. Another method is shown in figure 4-18. With a T square, draw horizontal line AB equal to the given length of side. With a T square and a 45° triangle, draw diagonals from A and B at 45° to AB. Erect perpendiculars from

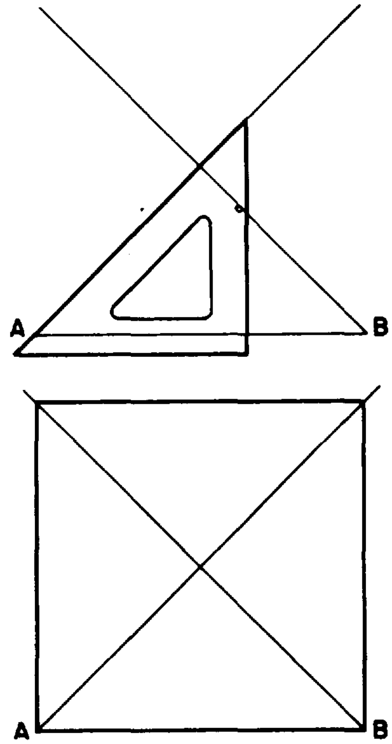

Figure 4-18.-Square with a given length of side.

A and B, intersecting the diagonals. Then connect the points of intersection.

SQUARE: GIVEN LENGTH OF DIAGONAL

Figure 4-19 shows a method of constructing a square with a given length of diagonal. Draw horizontal line AB, equal to the given length of the diagonal. Locate O at the center of AB, and lay off CD through O, perpendicular to and

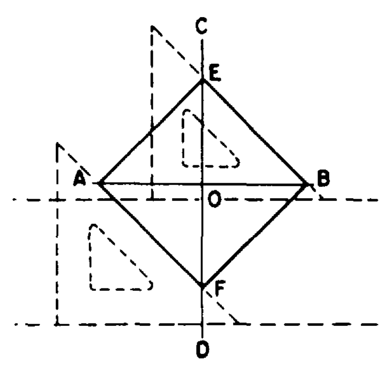

Figure 4-19.-Square with a given length of diagonal.

slightly longer than AB. Use a T square and a 45° triangle to draw AF and EB at 45° to AB and CD, Connect AE and FB.

SQUARE IN A GIVEN CIRCUMSCRIBED CIRCLE

Figure 4-20 shows a method of drawing a square in a given circumscribed circle. Draw the diameters AB and CD at right angles to each other, and connect the points where the diameters intersect the circumference of the circle.

SQUARE CIRCUMSCRIBED ON A GIVEN INSCRIBED CIRCLE

Figure 4-21 shows a method of circumscribing a square on a given inscribed circle, Draw diameters AB and CD at right angles to each other. Then draw each side of the square tangent to the point where a diameter intersects the circumference of the circle and perpendicular to the diameter.

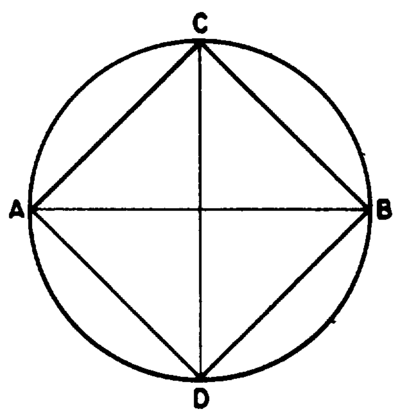

Figure 4-20.-Square in a given circumscribed circle.

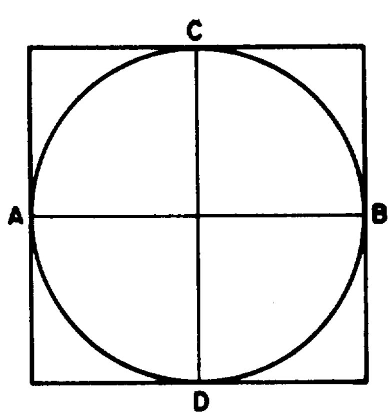

Figure 4-21.-Square on a given inscribed circle.

ANY REGULAR POLYGON IN A GIVEN CIRCUMSCRIBED CIRCLE

You can construct any regular polygon in a given circumscribed circle by trial and error with a drafting compass or dividers as shown in figure 4-22. To draw a nine-sided regular polygon in the circle shown, divide the circumference by trial and error with a compass or dividers into nine equal segments, and connect the points of intersection. To get a trial spread for a compass or dividers, divide the central angle subtended by the entire circle (360) by the number of sides of the polygon, in this case, by nine. Then, lay off the central angle quotient from the center of the circle to the circumference with a protractor.

ANY REGULAR POLYGON ON A GIVEN INSCRIBED CIRCLE

The same method (dividing the circumference into equal segments) can be used to construct a regular polygon on a given inscribed circle. In this case, however, instead of connecting the points of intersection on the circumference, you draw each side tangent to the circumference and

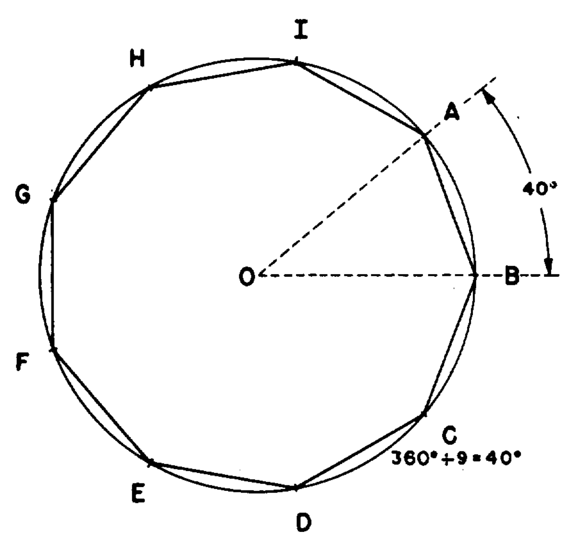

Figure 4-22.-Regular polygon in a given circumscribed circle.

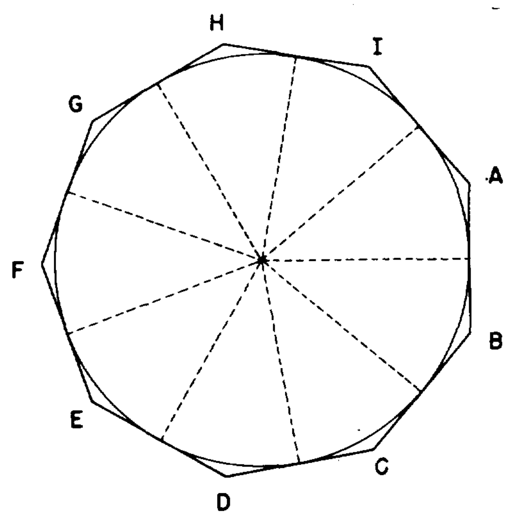

Figure 4-23.-Regular polygon on a given inscribed circle.

perpendicular to the radius at each point of intersection, as shown in figure 4-23.

ANY REGULAR POLYGON WITH A GIVEN LENGTH OF SIDE

Figure 4-24 shows a method of drawing any regular polygon with a given length of side. To draw a nine-sided regular polygon with length of side equal to AB, first extend AB to C, making CA equal to AB. With A as a center and AB (or CA) as a radius, draw a semicircle as shown. Divide the semicircle into nine equal segments from C to B, and draw radii from A to the points of intersection. The radius A2 is always the second side of the polygon.

Draw a circle through points A, B, and D. To do this, first erect perpendicular bisectors from DA and AB. The point of intersection of the bisectors is the center of the circle. The circle is the circumscribed circle of the polygon. To draw the remaining sides, extend the radii from the semicircle as shown, and connect the points where they intersect the circumscribed circle.

Besides the methods described for constructing any regular polygon, there are particular methods for constructing a regular pentagon, hexagon, or octagon.

REGULAR PENTAGON IN A GIVEN CIRCUMSCRIBED CIRCLE

Figure 4-25 shows a method of constructing a regular pentagon in a given circumscribed circle. Draw a horizontal diameter AB and a vertical diameter CD. Locate E, the midpoint of the radius OB. Set a compass to the spread between E and C, and, with E as a center, strike the arc CF. Set a compass to the spread between C and F, and, with C as a center, strike the arc GF. A line from G to C forms one side of the pentagon. Set a compass to GC and lay off this interval from C around the circle. Connect the points of intersection.

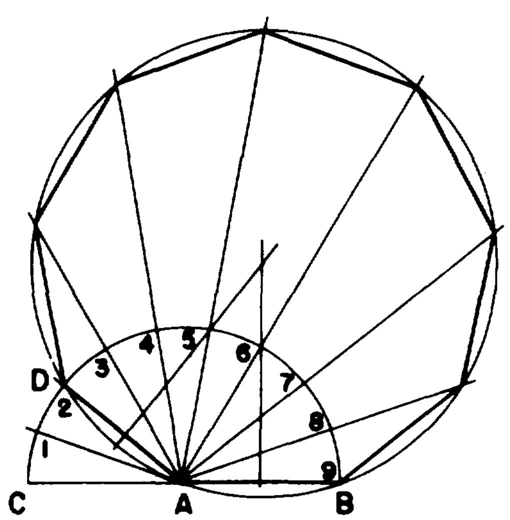

Figure 4-24.-Any regular polygon with a given length of side.

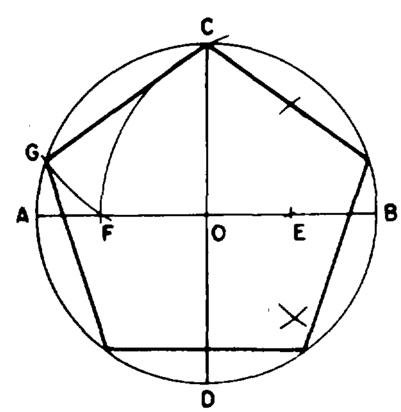

Figure 4-25.-Regular pentagon in a given circumscribed circle.

REGULAR PENTAGON ON A GIVEN INSCRIBED CIRCLE

To construct a regular pentagon on a given inscribed circle, determine the five equal intervals on the circle in the same manner. However, instead of connecting these points, draw each side of the figure tangent to the circle at a point of intersection.

REGULAR HEXAGON IN A GIVEN CIRCUMSCRIBED CIRCLE

Many bolt heads and nuts are hexagonal (six-sided) in shape. Figure 4-26 shows a method of constructing a regular hexagon in a given circumscribed circle. The diameter of the circumscribed circle has the same length as the long diameter of the hexagon. The radius of the circumscribed circle (which equals one-half the long diameter of the hexagon) is equal in length to the length of a side. Lay off the horizontal diameter AB and vertical diameter CD. OB is the radius of the circle. From C, draw a line CE equal to OB; then lay off this interval around the circle, and connect the points of intersection.

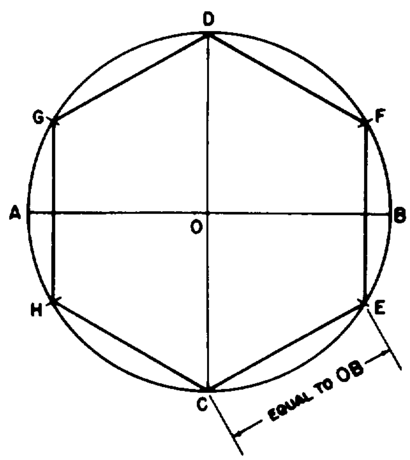

Figure 4-26.-Regular hexagon in a given circumscribed circle: one method.

Figure 4-27 shows another method of constructing a regular hexagon in a given circumscribed circle. Draw vertical diameter AB, and use a T square and a 30°/60° triangle to draw BC from B at 30° to the horizontal. Set a compass to BC, lay off this interval around the circumference, and connect the points of intersection.

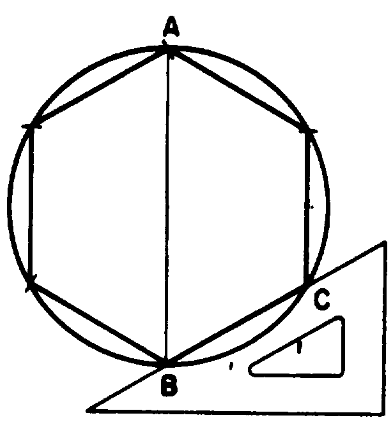

Figure 4-27.-Regular hexagon in a given circumscribed circle: another method.

REGULAR HEXAGON ON A GIVEN INSCRIBED CIRCLE

Figure 4-28 shows a method of constructing a regular hexagon on a given inscribed circle. Draw horizontal diameter AB and vertical center line. Draw lines tangent to the circle and perpendicular to AB at A and B. Use a T square and a 30°/60° triangle to draw the remaining sides of the figure tangent to the circle and at 30° to the horizontal.

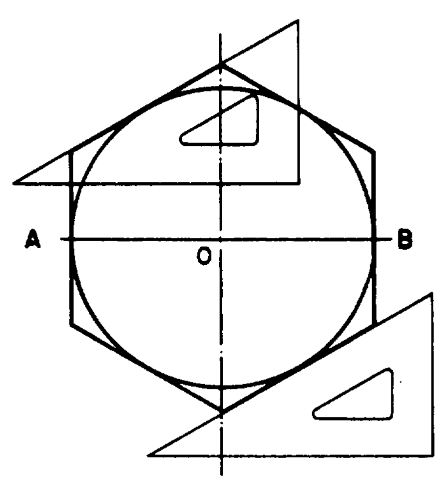

Figure 4-28.-Regular hexagon on a given inscribed circle.

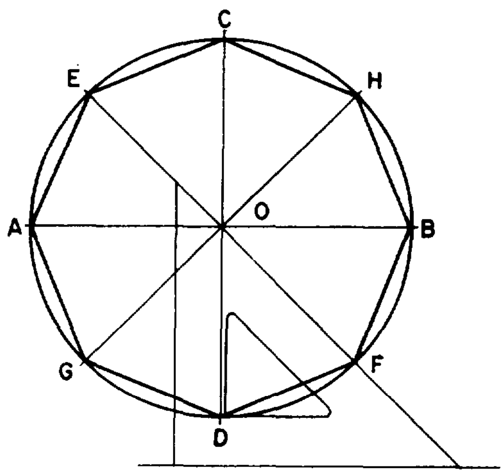

Figure 4-29.-Regular octagon in a given circumscribed circle.

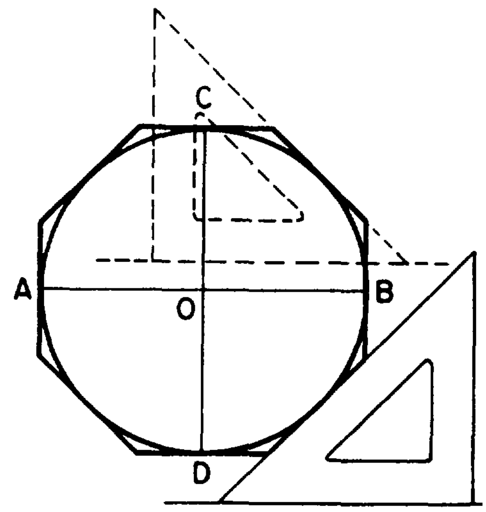

Figure 4-30.-Regular octagon around a given inscribed circle.

REGULAR OCTAGON IN A GIVEN CIRCUMSCRIBED CIRCLE

Figure 4-29 shows a method of constructing a regular octagon in a given circumscribed circle. Draw horizontal diameter AB and vertical diameter CD. Use a T square and a 45° triangle to draw additional diameters EF and GH at 45° to the horizontal. Connect the points where the diameters intersect the circle.

REGULAR OCTAGON AROUND A GIVEN INSCRIBED CIRCLE

Figure 4-30 shows a method of constructing a regular octagon around a given inscribed circle. Draw horizontal diameter AB and vertical diameter CD. Draw tangents at A, B, C, and D perpendicular to the diameters. Draw the remaining sides of the figure tangent to the circle at 45° to the horizontal.

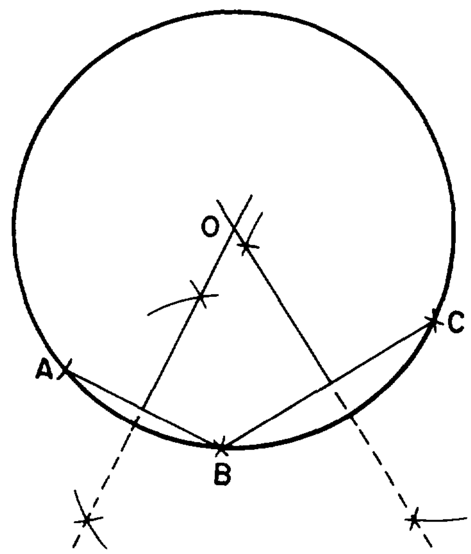

Figure 4-31.-Circle or arc through three points.

CIRCULAR CURVES

Many of the common geometrical constructions occurring in the drafting room are those involving circular curves. This section explains how to construct circular curves that may be required to satisfy varying conditions.

CIRCLE THROUGH THREE POINTS

In figure 4-31 the problem is to draw a circle (or a circular arc) that passes through points A, B, and C. Connect the points by lines and erect perpendicular bisectors as shown. The point of intersection of the perpendicular bisectors (O) is the center of the circle or arc passing through all three points.

LINE TANGENT TO A CIRCLE AT A GIVEN POINT

A line that is tangent to a circle at a given point is perpendicular to the radius that intersects the point. It follows that one method of drawing a line tangent to a circle at a given point is to draw the radius that intersects the point, and then draw the line tangent at the point of intersection and perpendicular to the radius.

Another method is shown in figure 4-32. To draw a line tangent to the circle at P, set a compass to the radius of the circle, and, with P as a center, strike an arc that intersects the circle at A. With the compass still set to the radius of the circle, use A as a center and strike an arc that intersects the first arc at B. With B as a center and the compass still set to the radius of the circle, strike another arc. A line through the point of intersection (0) of the last drawn arc and through P is tangent to the circle at P.

CIRCULAR ARC OF A GIVEN RADIUS TANGENT TO TWO STRAIGHT LINES

Drawing a fillet or round comprises the problem of drawing a circular arc of a given radius tangent to two nonparallel lines.

Figure 4-33 shows a method that can be used when the two nonparallel lines form a right angle. AB is the given radius of the arc. Set a compass to this radius, and, with the point of intersection of the lines as a center, strike an arc intersecting the lines at C and D. With C and D as centers and the same radius, strike intersecting arcs as shown. The point of intersection of these arcs (0) is the center of the circle of which an arc of the given radius is tangent to the lines.

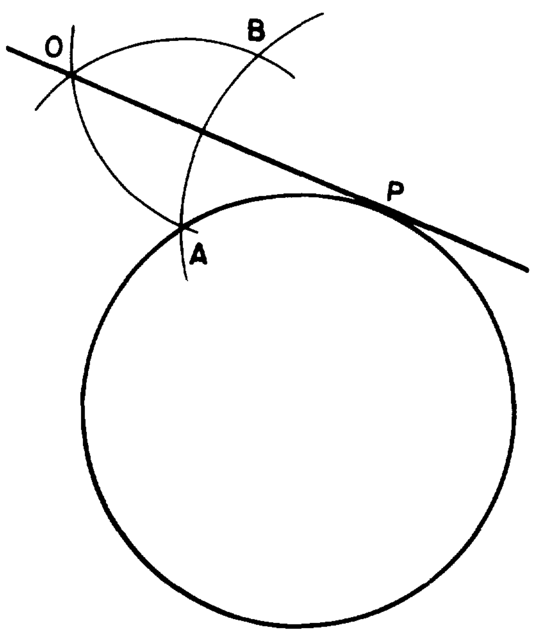

Figure 4-32.-Line tangent to a given point on a circle.

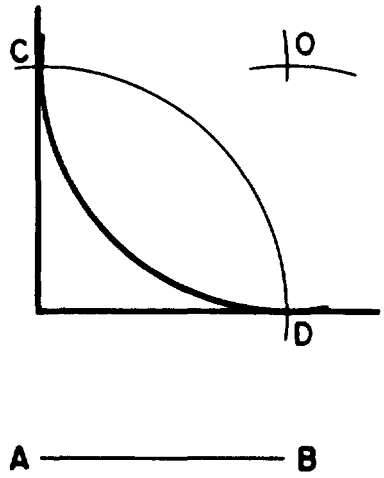

Figure 4-33.-Circular arc tangent to two lines that form a right angle.

Figure 4-34 shows a method that can be used regardless of the size of the angle formed by the lines. Again AB equals the given radius of the arc, and the problem is to draw an arc with radius equal to AB, tangent to CD and EF. Draw GH parallel to CD and at a distance from CD equal to the given radius of the arc. Draw IJ parallel to EF and also at a distance equal to the given radius of the arc. The point of intersection between GH and IJ (P) is the center of the circle of which an arc of the given radius is tangent to CD and EF.

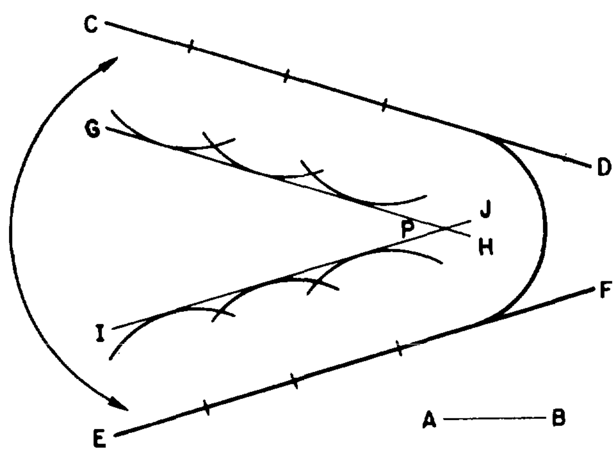

Figure 4-34.-Circular arc tangent to two lines that form any angle.

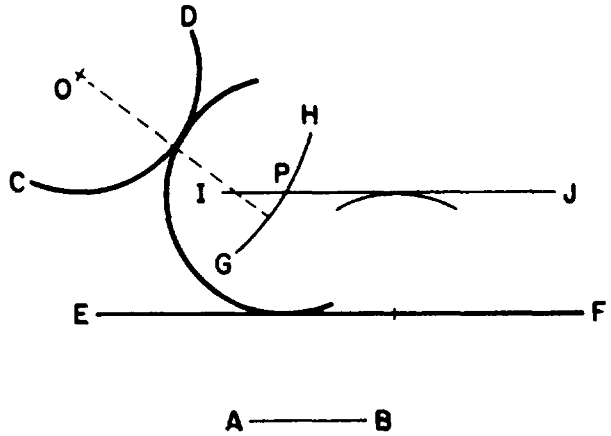

Figure 4-35.-Circular arc tangent to a straight line and another circular arc.

CIRCULAR ARC OF A GIVEN RADIUS TANGENT TO A STRAIGHT LINE AND TO ANOTHER CIRCULAR ARC

The problem in figure 4-35 is to draw a circular arc with a radius equal to AB, tangent to the circular arc CD and to the straight line EF. Set a compass to a radius equal to the radius of the circular arc CD plus the given radius AB (which is indicated by the dashed line shown), and, with O as a center, strike the arc GH. Draw a line IJ parallel to EF at a distance from EF equal to AB. The point of intersection (P) between GH and IJ is the center of the circle of which an arc of the given radius is tangent to CD and EF.

CIRCULAR ARC OF A GIVEN RADIUS TANGENT TO TWO OTHER CIRCULAR ARCS

The problem in figure 4-36 is to draw an arc with a radius equal to AB, tangent to the circular arcs CD and EF. Set a compass to a spread equal to the radius of arc CD plus AB (indicated by the left-hand dashed line), and, with O as a center, strike an arc. Set the compass to a spread equal to the radius of arc EF plus AB (indicated by the right-hand dashed line), and, with O´ as a center, strike an intersecting arc. The point of intersection between the two arcs (P) is the center of the circle of which an arc of given radius is tangent to arcs CD and EF.

In figure 4-36 the circular arcs CD and EF curve in **opposite** directions. In figure 4-37 the problem is to draw an arc with radius equal to AB, tangent to two circular arcs, CD and EF, that curve in the **same** direction.

Set a compass to a radius equal to the radius of EF less AB, and, with O´ as a center, strike an arc. Then, set a compass to a radius equal to the radius of arc CD plus line AB, and, with O as center, strike an intersecting arc at P. The point of intersection of these two arcs is the center of the circle of which an arc of the given radius is tangent to CD and EF.

When a circular arc is tangent to another, it is commonly the case that the two arcs curve in opposite directions. However, an arc may be drawn tangent to another with both curving in the same direction. In a case of this kind, the tangent arc is said to enclose the other.

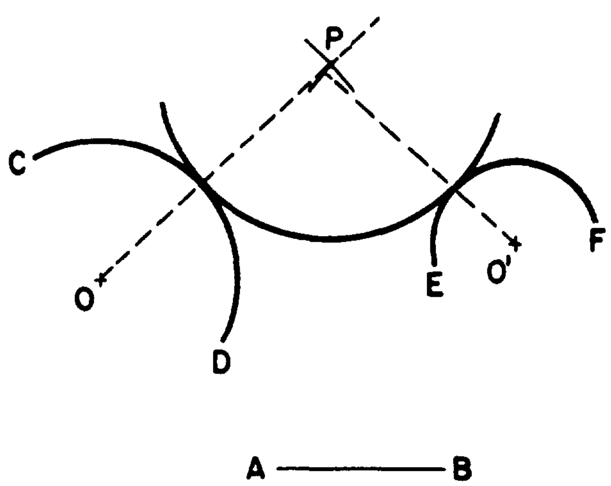

Figure 4-36.-Circular arc tangent to two other circular arcs.

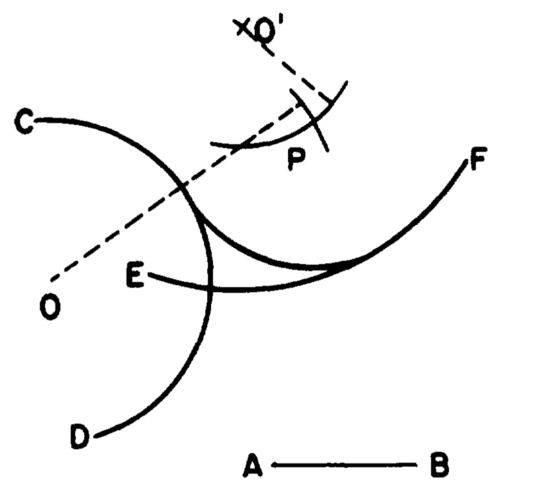

Figure 4-37.-Circular arc tangent to arcs that curve in the same direction.

An arc tangent to two others may enclose both, or it may enclose only one and not the other. In figure 4-38 the problem is to draw a circular arc with a radius equal to AB, tangent to and enclosing both arcs CD and EF. Set a compass to a radius equal to AB less the radius of CD (indicated by the dashed line from O), and, with O as a center, strike an arc. Set the compass to a radius equal to AB less the radius of EF (indicated by the dashed line from O´), and, with O´ as a center, strike an intersecting arc at P. The point of intersection of these two arcs is the center of a circle of which an arc of given radius is tangent to, and encloses, both arcs CD and EF.

In figure 4-39 the problem is to draw a circular arc with a radius equal to AB, tangent to, and enclosing, CD, and tangent to, but NOT enclosing, EF. Set a compass to a radius equal to AB less the radius of arc CD (indicated by the dashed line from 0), and, with O as a center, strike an arc, Set the compass to AB plus the radius of EF (as indicated by the dashed line from O´), and, with O´ as a center, strike an intersecting arc at P. The point of intersection of the two arcs is the center of a circle of which an arc of the given radius is tangent to and encloses arc CD and also is tangent to, but does not enclose, arc EF.

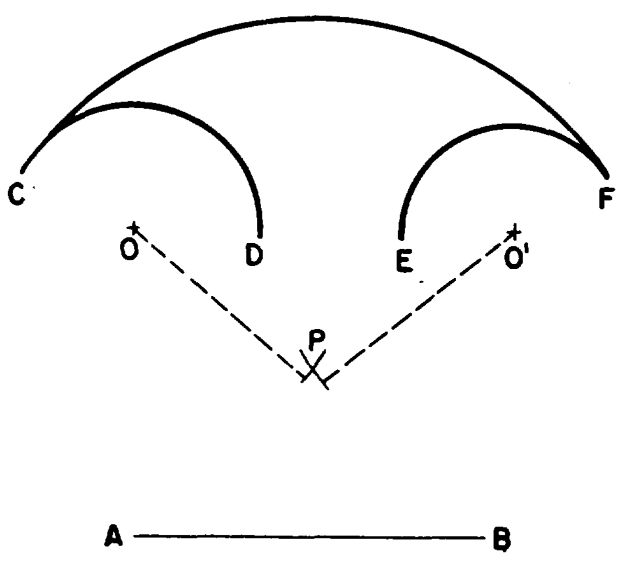

Figure 4-38.-Circular arc tangent to and enclosing two other circular arcs.

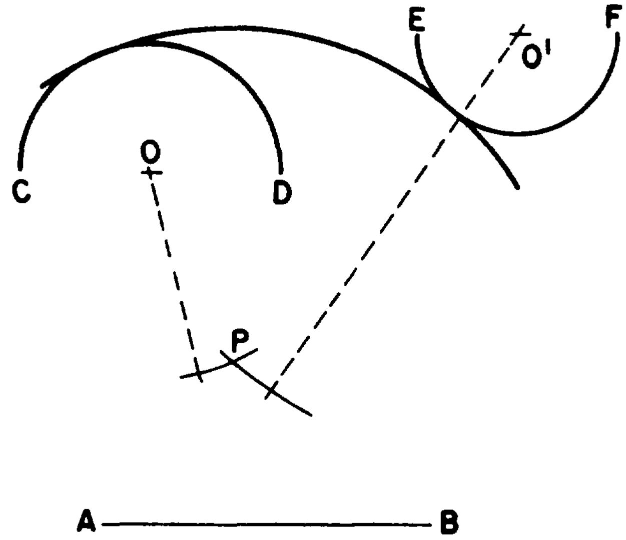

Figure 4-39.-Circular arc tangent to and enclosing one arc and tangent to, but not enclosing, another.

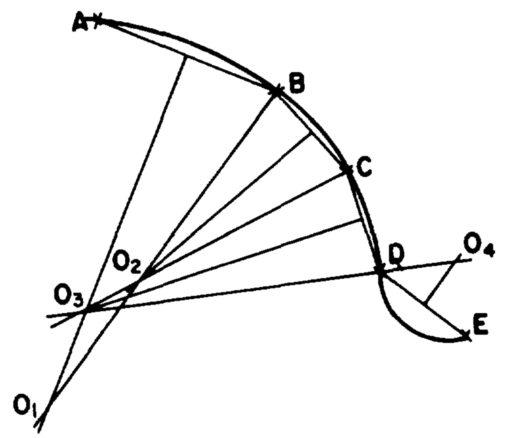

Figure 4-40.-Curve composed of a series of consecutive tangent circular arcs.

COMPOUND CURVES

A curve that is made up of a series of successive tangent circular arcs is called a compound curve. In figure 4-40 the problem is to construct a compound curve passing through given points A, B, C, D, and E. First, connect the points by straight lines. The straight line between each pair of points constitutes the chord of the arc through the points.

Erect a perpendicular bisector from AB. Select an appropriate point O_1 on the bisector as a center, and draw the arc AB. From O_1, draw the radius O_1B. From BC, erect a perpendicular bisector. The point of intersection O_2 between this bisector and the radius O_1B is the center for the arc BC. Draw the radius O_2C, and erect a perpendicular bisector from CD. The point of intersection O_3 of this bisector and the extension of O_2C is the center for the arc CD.

To continue the curve from D to E, you must reverse the direction of curvature. Draw the radius O_3D, and erect a perpendicular bisector from DE on the opposite side of the curve from those previously erected. The point of intersection of this bisector and the extension of O_3D is the center of the arc DE.

REVERSE, OR OGEE, CURVE

A reverse, or ogee, curve is composed of two consecutive tangent circular arcs that curve in opposite directions,

Figure 4-41 shows a method of connecting two parallel lines by a reverse curve tangent to the lines. The problem is to construct a reverse curve tangent to the upper line at A and to the lower line at B.

Connect A and B by a straight line AB. Select on AB point C where you want to have the reverse curve change direction. Erect perpendicular bisectors from BC and CA, and erect perpendiculars from B and A. The points of intersection between the perpendiculars (O_1 and O_2) are the centers for the arcs BC and CA.

Figure 4-42 shows a method of constructing a reverse curve tangent to three intersecting straight lines. The problem is to draw a reverse curve tangent to the three lines that intersect at points A and B. Select on AB point C where you want the reverse curve to change direction. Lay off from A a distance equal to AC to establish point D. Erect a perpendicular from D and another from C. The point of intersection of these perpendiculars (O_1) is the center of the arc DC.

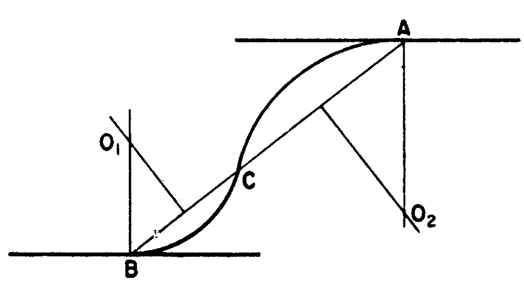

Figure 4-41.—Reverse curve connecting and tangent to two parallel lines.

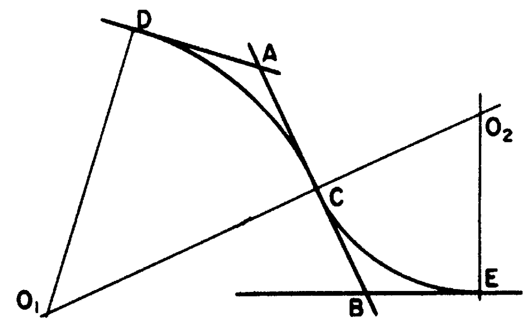

Figure 4-42.—Reverse curve tangent to three intersecting straight lines.

Lay off from B a distance equal to CB to establish point E. Erect a perpendicular from E, and extend O_1C to intersect it. The point of intersection (O_2) is the center of the arc CE.

NONCIRCULAR CURVES

The basic uniform noncircular curves are the ellipse, the parabola, and the hyperbola. These curves are derived from conic sections as shown in figure 4-43. The circle itself (not shown, but a curve formed by a plane passed through a cone perpendicular to the vertical axis) is also derived from a conic section.

This section describes methods of constructing the ellipse only. Methods of constructing the hyperbola are given in *Engineering Drawing* by French and Vierck and in *Architectural Graphic Standards.*

Of the many different ways to construct an ellispe, the three most common are as follows: the pin-and-string method, the four-center method, and the concentric-circle method. The method you should use will depend on the size of the ellipse and where it is to be used.

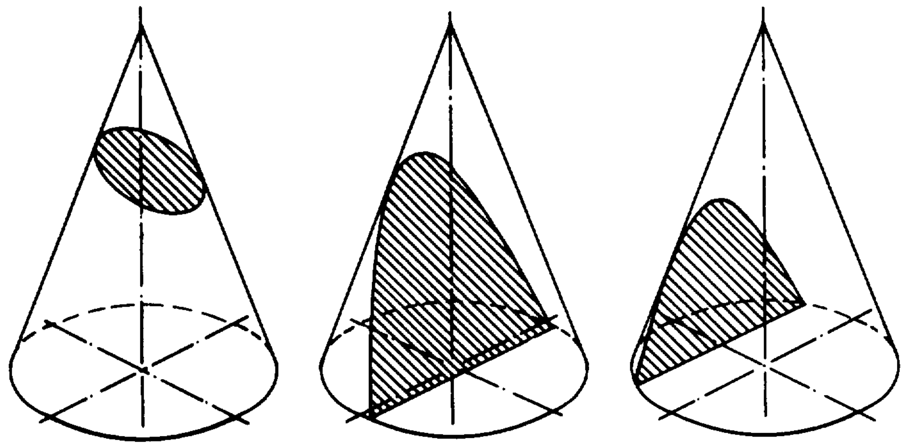

Figure 4-43.-Conic sections: ellipse, parabola, and hyperbula (left to right).

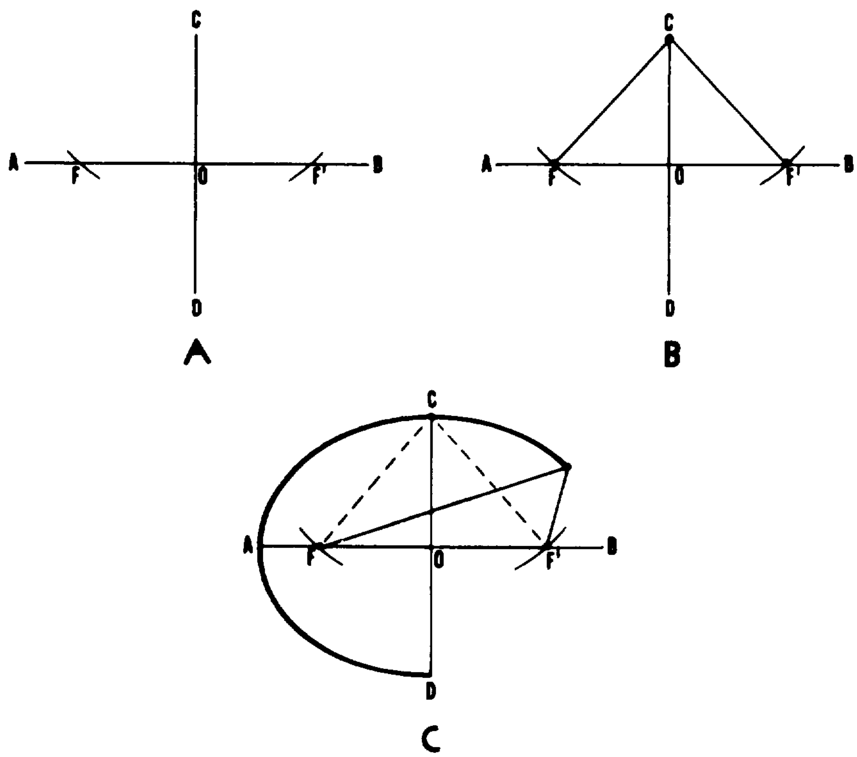

Figure 4-44.-Ellipse by pin-and-string method.

ELLIPSE BY PIN-AND-STRING METHOD

The dimensions of an ellipse are given in terms of the lengths of the major (longer) and minor (shorter) axes. Figure 4-44 shows a method of constructing an ellipse that is called the pin-and-string method. The problem is to construct an ellipse with a major axis, AB, and a minor axis, CD. Set a compass to one-half the length of AB, and, with C as a center, strike arcs intersecting AB at F and F´. The points F and F´ are called the foci of the ellipse. Set a pin at point C, another at F, and a third at F´. Tie the end of a piece of string to the pin at F, pass the string around the pin at C, draw it taut, and fasten it to the pin at F´. Remove the pin at C, place the pencil point in the bight of the string, and draw the ellipse as shown in view C, keeping the string taut all the way around.

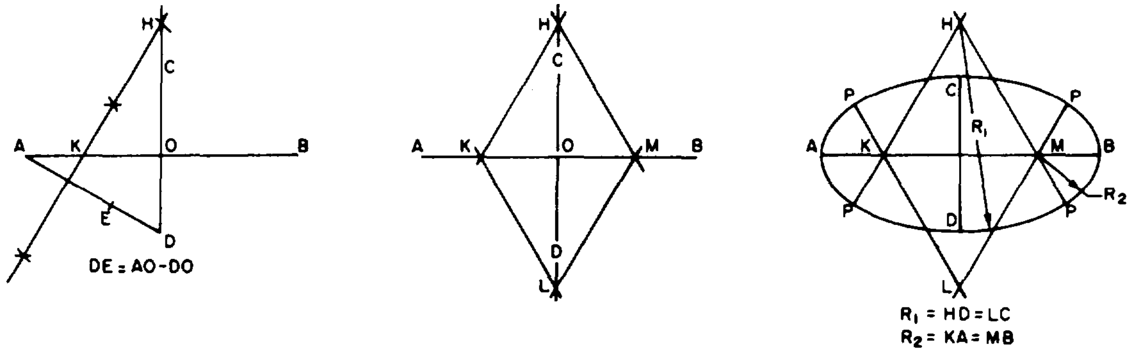

Figure 4-45.-Ellipse by four-center method.

ELLIPSE BY FOUR-CENTER METHOD

The four-center method is used for small ellipses. Given major axis, AB, and minor axis, CD, mutually perpendicular at their midpoint, O, as shown in figure 4-45, draw AD, connecting the end points of the two axes. With the dividers set to DO, measure DO along AO and reset the dividers on the remaining distance to O. With the difference of semiaxes thus set on the dividers, mark off DE equal to AO minus DO. Draw perpendicular bisector AE, and extend it to intersect the major axis at K and the minor axis extended at H. With the dividers, mark off OM equal to OK, and OL equal to OH. With H as a center and radius R_1 equal to HD, draw the bottom arc. With L as a center and the same radius as R_1, draw the top arc. With M as a center and the radius R_2 equal to MB draw the end arc. With K as a center and the same radius, R_2, draw the end arc. The four circular arcs thus drawn meet, in common points of tangency, P, at the ends of their radii in their lines of centers.

ELLIPSE BY CONCENTRIC-CIRCLE METHOD

Figure 4-46 shows the concentric-circle method of drawing an ellipse. With the point of intersection between the axes as a center, draw two concentric circles (circles with a common center), one with a diameter equal to the major axis and the other with a diameter equal to the minor axis, as shown in figure 4-46, view A. Draw a number of diameters as shown in figure 4-46, view B. From the point of intersection of each diameter with the larger circle, draw a vertical line; and from the point of intersection of each diameter with the smaller circle, draw an intersecting horizontal line, as shown in figure 4-46, view C. Draw the ellipse through the points of intersection, as shown in figure 4-46, view D, with a french curve.

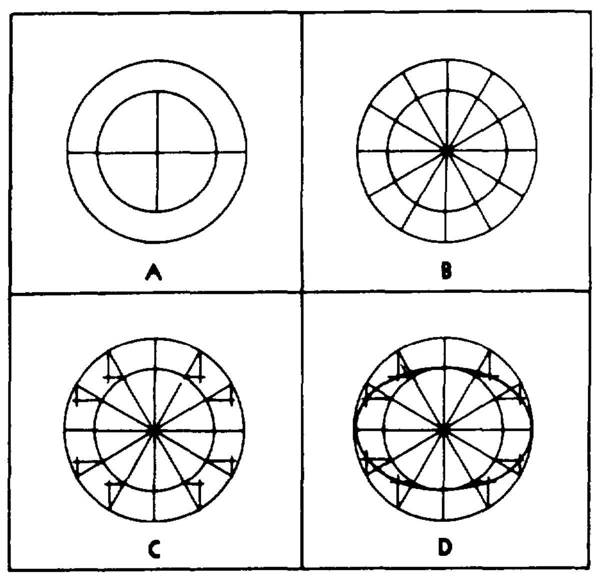

Figure 4-46.-Ellipse by concentric-circle method.